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Abstract:

Sustained energy price increases in the United States have preceded declines in economic activity as far back as 1890. This finding applies to two different historical GDP data sets. It suggests a much longer national experience with rising energy prices that began well before the period after World War Two. This problem emerged well before the US transition towards petroleum products when coal was an important energy source. This relationship varies with the state of the economy and appears less evident during some periods, as in the years following the 1929 stock market crash.

Keywords: economic history, supply shocks, energy and the economy

JEL Classifications: Q43, N51, N71, O51

1. Introduction

Oil supply shocks have dominated the political and economic landscape during the last three decades of the twentieth century. These events often caused economic recession and changed political leadership within the United States (Blinder and Watson, 2016). Today many news organizations and central banks around the globe follow oil price movements with intense interest. Although recent studies have downplayed the significance of oil supply shocks under current conditions, this topic continues to attract much attention because political unrest and military conflicts remain important factors in some critical petroleum supply regions (Jaffe and Elass, 2015). These areas continue to supply significant amounts of crude oil, even with the recent expansion with U.S. production.

It is appropriate that the oil supply shock literature has focused on the years after World War Two. During this period oil began replacing coal as the energy engine for the U.S. economy. It is also the era when global oil production began to shift towards the Middle East. Founded in 1963, the Organization of Petroleum Exporting Countries (OPEC) eventually became a dominant energy supplier whose decisions greatly affected global petroleum markets. However, this focus masks the prior U.S. experience with energy shocks in previous decades. Pre-war energy price shocks have been very large and approximately similar in magnitude to oil price shocks after World War Two, as will be shown below. This analysis extends coverage to the earlier U.S. experience and tries to develop meaningful conclusions from this historical record about the impact of energy price shocks on the economy. A key finding is that sustained energy price increases in the United States have preceded many declines in economic activity as far back as 1890.

There are several important reasons for extending this discussion to the earlier years. First, major energy supply disruptions are relatively uncommon events, limited to the 1970s with smaller hostile curtailments in late 1956 and 1990. Expanding the sample to include more natural “experiments” may provide additional insights. Second, it is important to know if and when price shocks have been important to the US economy and under what economic conditions. Energy price shocks are only one of many factors that could lead to economic recession. Its impact on the economy will depend upon the presence or absence of these other factors. Third, understanding the economy’s response prior to its dependence upon petroleum may be particularly valuable for developing insights about a range of current issues. If other energy forms like coal also created similar problems, it suggests that policy analysis might want to be concerned about sudden price movements for other energy forms like natural gas and electricity, particularly as the economy begins its transition towards electricity and away from coal, oil and other carbon-intensive fuels. Fourth, it may be illuminating to study a period when the US economy produced virtually all energy that it consumed rather than import significant volumes. If previous periods indicate significant economic costs from energy shocks, the problem may have less to do with whether energy sources are imported or produced domestically. And fifth, there are advantages to studying a period when energy use represented a much larger share of the economy than it does today. Although many factors and conditions shape the economy’s response to energy price shocks, the relative dependence upon energy inputs could potentially be important.

The next section discusses previous studies of energy price shocks and how they relate to the long-run historical experience considered here. Section 3 examines the 1890-1930 period and the growing importance of coal mining and the organization of coal unions. Section 4 discusses the historical data set and its principal properties. Section 5 documents the econometric evidence on the oil-economy response across two very different periods that precede and follow the Great Depression of the 1930s. Due to the importance of many other factors causing economic recessions, the estimates test robustness by incorporating various controls and sample sizes for excluding major wars, depressions, financial collapses and rapidly growing global oil demand. Importantly, the analysis demonstrates these results for two different historical estimates for economic growth. Summary remarks are outlined in the final section.

2. Past Studies

This approach builds upon two recent efforts to probe the historical "roots" of energy supply shocks and their impact on the economy. Hamilton (2012) reviews a number of very large oil price shocks and emphasizes the role played by geopolitical and military events that are largely external to oil consumers, oil suppliers from more stable regions and macroeconomic policy. A second important contribution is the analysis by van de Ven and Fouquet (2014) of the UK experience with a combination of coal and oil price shocks over several centuries. These authors employ the long and rich data available for the British economy and show that there are important similarities and differences between major time periods.

A number of studies have evaluated the economic impacts of oil price shocks, a fact that is amply demonstrated by several important articles that review the literature (Brown and Yücel, 2002, Jones, Leiby and Paik, 2004, and Kilian, 2008). Rather than repeat many of the insights from these review papers, this section will briefly mention a few points that tie directly to the current effort. Surprise price shocks lasting more than a few quarters and sustained over at least a year appear more debilitating that simple oil price oscillation (Hamilton, 1983, 1996). I will use the term "sustained price shocks" in the sections below to differentiate these sharp, sudden and unexpected disruptive price movements from price oscillations in the absence of a major market correction or adjustment. Sustained price shocks need not be permanent, but they should last for more than a quarter and should be sufficiently disruptive to lead directly to an underutilized capital stock.

Oil price shocks caused economic recessions in other OECD countries, regardless of whether these nations imported or exported petroleum (Bruno and Sachs, 1985, Mork, Olsen and Mysen, 1994, and Jiménez-Rodríguez and Sánchez, 2005). Smaller price movements appearing in many years after the 1970s had very little if any influence on economic performance, e.g., see the exchange between Hooker (1996) and Hamilton (1996). Similarly, oil price declines had no detectable effects (Mork 1989). Recent studies (e.g., Kilian 2009) indicate the importance of separating oil supply from oil demand shocks. Finally, a series of recent studies have shown that although oil price shocks still matter for the economy, the economic impacts are less (Nordhaus, 2007, Blanchard and Galí, 2010, and Blinder and Rudd, 2013) than in the past (Hickman *et al*, 1987). Several researchers have argued that the nature of this oil price shock has changed quite dramatically over time. Naccache (2010) explained the weakening of the oil-macroeconomic relationship by the increasing experience with “slow” rather than sudden oil price increases. Nordhaus (2007) too emphasized that oil price movements in more recent periods occur more gradually over relatively long periods rather than as sudden surprise jolts. Finally, Gronwald (2012) provided convincing evidence of the dominant effect of the 1973-74 oil price shock in explaining poor macroeconomic performances, implying that many later price movements were not really price shocks in the same sense of earlier experiences.

For the most part, this literature has focused exclusively on oil prices in the period after World War Two. Important exceptions include an analysis of west coast gasoline rationing in the 1920s (Olmstead and Rhode, 1985) and an assessment of oil price increases on industrial production during the interwar period (Mcmillin and Parker, 1994). Both studies document that these regional price shocks during these interwar years were accompanied by sharp downward movements in regional output and employment but not necessarily in their national counterparts.

3. The Pre-World-War-Two Period

In 1890 the fossil fuel transition within the United States was beginning to evolve, with coal becoming the dominant energy source (Figure 1). Coal was used for power, first in industrial processes and later in electric power in the early 20th century. The growth in electricity replaced petroleum in lighting applications, but eventually oil became the major fuel in transportation. During World War Two, petroleum became the dominant U.S. energy source economywide, although other fossil fuels (coal and natural gas) have also remained important.

Energy was substantially more important for the economy in the 1890-1930 period than after World War Two. Per dollar of real GDP, coal use intensity peaked around World War One and dominated the trend in energy intensity[1] until after World War Two, as shown in Figure 2. Petroleum use intensity emerged as an important contributor between the major wars, but total energy intensity declined substantially with coal intensity after 1920.

The economy depended mostly upon domestic rather than imported energy supplies during this earlier period. Although coal and oil are two energy sources that can be traded relatively easily, Figure 3 shows that US coal imports have never comprised an important share of the domestic market and that oil imports were not important until after 1970.[2]

Strikes by labor organizations and unions in the coal industry in the early twentieth century happened much more frequently than elsewhere in the economy (Fishback, 1992). More man-days were lost and a larger percentage of the coal workforce was affected than in other sectors.

During the early years of the 1890 decade, organizations representing coal workers extended their presence piecemeal, focusing upon one small strike after another (Blatz, 1991). Organization efforts usually focused on work rules and local issues at a single or several coal mines. Coal prices were relatively stable in these early years. The United Mine Workers of

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[1] Energy intensity trends are based upon GDP estimates (see Data Appendix) and primary energy consumption reported by U.S. Energy Information Administration (2011). The latter are reported for every five years only prior to 1949. For this reason, it is not possible to weight the energy price shocks by energy intensity in the regressions.
[2] Oil import shares for 1910-2015 and coal import shares for 1970-2015 are computed from annual data derived from the US Energy Information Administration. Coal import shares prior to 1970 are computed as the percent of derived coal consumption (production + imports – exports) from US Bureau of the Census (1975) Historical Statistics of the United States, Colonial Times to 1970, Part 1. Series M 93-106. Coal imports from the two sources are from the same source and match exactly for the period that they both report, 1970-2015. Net natural gas imports first became positive but by very small amounts in 1958 (American Gas Association (1978), pp. 23).

America (UMWA) organized a nationwide strike in bituminous industry in 1897. The union won recognition from many coal mine operators stretching from western Pennsylvania to Illinois.

UMWA organized an industrywide strike for workers in bituminous coal in 1900 resulting in a 10 percent increase in wages. Nationwide, BLS coal prices increased 9.5% faster than during the previous year. The following year, the US economy grew by 2.8 percentage points less than the previous year. These events set the stage for the much-publicized coal strike of 1902 that was eventually suspended by a commission established by President Theodore Roosevelt. UMWA won recognition for representing anthracite coal workers in eastern Pennsylvania and raised wages. Nationwide, BLS coal prices increased 5.5 percentage points faster than during the previous year. The following year, the US economy grew by 7.4 percentage points less than the previous year.

Figure 4 shows the time profile of annual changes in the average energy price since 1890. This figure clearly documents why economists studying the energy price shock problem should be fascinated with this previous period. Energy price changes prior to 1947 displayed similar patterns to those after 1947 and in some cases represented larger annual price changes than during the later years. These earlier energy price movements happened at a time when the economy experienced a much greater dependence on energy sources per dollar of real GDP.

4. Data Sources and Properties

Historical annual data on real GDP was combined with an annual series on energy prices derived principally from the U.S. Bureau of Labor Statistics.[3] The Millennial Edition of *Historical Statistics of the United States* edited by Carter *et al* (2006) developed an extensive historical data set (Sutch, 2006) on the US economy and its growth rate since 1790 with the goal of achieving consistency throughout the horizon. They label their preferred measure for inflation-adjusted economic growth as the "Millennial" series. They based their gross domestic product (GDP) estimates on appropriate adjustments to the standard Kuznets-Kendrick-Gallman gross national product (GNP) series used by other researchers because it is the only one based directly on data. They also provide an alternative Johnston-Williamson indirect measure based upon regression-filtered series that will be referenced as "Alternative GDP" below when robustness tests are evaluated for a second historical data set on economic growth.[4] The availability of a second data set on economic growth is important for robustness testing, given the significant challenges in constructing a unified and consistent set of estimates. Further details on the specifics of these two series can be found in the full description of the Millennial project provided by Sutch (2006).

In addition, energy price series are available from the U.S. Bureau of Labor Statistics (BLS) for aggregate fuel and power that includes all energy forms, including major fossil fuel sources such as coal, oil and natural gas. The BLS index covers domestic but not international

[3] The Data Appendix explains the construction of the real GDP and energy price series for the full 1890-2014 sample.

[4] Although the estimated equations below differ from each other, the two real GDP series appear somewhat similar both in the data summary presented in Table 1 as well as time-series charts comparing economic growth rates in the two series that are available from the author.

crude oil prices. BP Statistics (2015) provides data for domestic crude oil through 1944 and for international crude oil between 1945 and 2014.

All variables are converted to first differences in their logarithms. Table 1 summarizes the means and standard deviations of the change in each variable over the 1891-2014 period.[5]

5. Empirical Evidence

The analysis initially considered the periods before the 1929 Stock Market Crash and after the Great Depression as two separate samples.[6] One of the interesting conclusions from evaluating these subsamples was the importance of lagged GDP effects covering at least two years for the earlier period. This longer lag length for the earlier period may reflect the fact that reconstructed historical data tends to contain some smoothing to reduce the volatility in the output series. It will be important to include these lagged GDP effects when evaluating the combined-sample data that are discussed below.

A second essential finding was that the estimates based upon annual data for the period after 1947 served as a useful benchmark for comparison with estimates based upon quarterly data that have appeared in many previous studies. Energy price increases tend to be followed by slower GDP growth, whereas the effect of GDP growth on energy prices generally is insignificant. Moreover, based upon either the BLS or BP oil price series as well as the aggregate

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[5] Adjusted Dickey-Fuller tests reported in Huntington (2016) indicate that energy price and real GDP levels are not stationary (unit roots cannot be rejected) but their first differences are stationary. As a caveat, although the full sample includes 125 observations, Pindyck (1999) warns about the limitations of unit root tests in limited samples when the mean-reverting process is relatively slow. Johansen tests indicate that the levels of energy prices and real GDP are not cointegrated. For these reason, the estimates are based upon first differences in the data.

[6] Interested readers are referred to Huntington (2016) for a range of tests for choosing the lag length and exploring robustness in the specifications in these subperiods. This analysis also provides a chart showing the impulse responses for the nominal energy price shock equal to the unexpected one standard deviation of the error term.

energy price variable, the largest economic impacts occur approximately one year after the energy price shock. This timing is comparable to the quarterly results where the largest response occurs four quarters after the shock. It is often the fourth-quarter lagged response that is significant at conventional levels in the studies evaluating quarterly data. Although annual energy price movements may understate the volatility of quarterly price fluctuations, they may be more relevant for representing sustained price shifts that cause the capital stock to become seriously underutilized. The events surrounding the oil price shock may be as important as the actual oil-price trajectory itself.

A third interesting finding is that the significance of the annual oil or aggregate energy price effect after World War Two is robust to a number of different specifications, including separating price increases from price decreases, price increases due to oil supply disruptions from other price movements, real versus nominal energy prices, and for different breaks in the sample (before 2009, before 2002, before and after 1973). These additional tests are important in order to control for other important factors that could influence the response of the economy to oil price movements.

The rest of this section evaluates the combined period of the years preceding 1930 and the years following either 1933 or 1947. It is important to exclude the Great Depression years of 1930-33 where factors other than energy prices were clearly influencing economic growth. As a robustness test, it is also interesting to exclude the years 1930-47, because many of the energy price movements in this period were regional rather than national shocks.

The estimates below control for the Great Recession's impact on the economy in 2009. Excluding the dummy variable for 2009 increases the magnitude and significance of the lagged price effects, but the basic conclusions are very similar. Without this control, too much of the economic deterioration would be attributed to the rapid crude oil price increase in 2008 when clearly the financial collapse and other related factors were the principal cause.

In evaluating the period prior to 1930, it is important to control through a dummy variable for the substantial energy price increase in 1917 due to the USA joining the Allies. This control influences the economic activity response in 1918 because energy price changes have a one-year lagged effect. This response most likely reflected a demand-pull rather than supply-push stimulus to petroleum prices.

The specifications initially used two lags for energy prices and real GDP because two lags were critical for explaining relationships prior to the Great Depression. Data constraints on other reasonable variables restrict the approach to be a bivariate (low dimension) model that limits the use of a structural VAR approach to differentiate supply and demand shocks (Kilian, 2009, and Kilian and Murphy, 2012).[7] Although the specification does not establish causality as convincingly as a structural approach, it does explain the conditional expectation of GDP growth provided that there is information about lagged values for GDP growth and oil price changes.

Granger causality tests in Table 2 show that energy price shocks precede aggregate economic downturns over this combined sample regardless of which years are excluded or

[7] The supplementary analysis by Huntington (2016, p.9) discusses this data problem in greater depth. With lower-frequency annual rather than monthly data, there exists a greater chance that identified shocks are actually a coincidence (van de Ven and Fouquet, 2014, p.10). One candidate variable for inclusion in an SVAR would be aggregate energy production. Unfortunately, aggregate conditions often reveal little about oil market shortfalls concentrated in the Persian Gulf and neighboring countries because production offsets often occur in the non-impacted areas (Hamilton, 2003, 2013). Applying SVAR under these conditions could lead to counterintuitive results. Similar concerns would also result in coal markets, where regional rather than national shortfalls are often the critical factor.

whether oil prices are deflated or not. For example, they reject the hypothesis that past nominal energy prices can be excluded as a predictor of economic growth for the period prior to 1933 and after 1947 with chi-square=14.80 (significant at 0.1% level). Tests applied to the equation explaining energy prices do not reject excluding past economic growth as a predictor in any case.

Estimated coefficients for explaining real GDP since 1892 when it is measured by the Millennial series are reported in Table 3. Coefficients and standard errors are shown for the constant, two lagged values of the energy price series and real GDP, and dummy control variables for economic growth in 1918 and 2009. Specifications with both nominal (columns 1 and 3) and real (columns 2 and 4) energy prices are shown for robustness. Nominal oil price movements would be the key driver in a neo-Keynesian system with downward wage and price stickiness in the short run. Nominal prices are also likely to be more exogenous than real oil prices because the shock would exclude the endogenous response of inflationary policies. However, additional estimates based upon real oil prices have also been evaluated as a robustness test. This specification would represent the oil price movement as a technology shock in a real-business-cycle framework that also included economic dislocations between sectors and an underutilized capital stock.[8]

The explanatory power of the equations that exclude 1930-47 in the last two columns lies between 14.6% and 18.9%, and these estimates are noticeably higher than those that exclude only 1930-33. The poor performance of the sample that excludes only 1930-33 is due to

[8] Although his arguments favor the neo-Keynesian framework, Mankiw (1989) provides a straightforward discussion of these two approaches for explaining aggregate output fluctuations.

the insignificant effects for the first and second year lagged effects for real GDP. The lagged energy price coefficients, however, are significant in either sample and with either nominal or real prices. When lagged two years, the nominal energy price coefficient is significant when 1930-47 is excluded and just barely misses significance (at 5.5%) when only 1930-33 is excluded. In addition, controlling for the stimulating effect of World War One on economic growth is also important, as evidenced by its significant coefficient.

Given the relatively low explanatory power of these equations, it might be useful to evaluate whether the responses shifted after the Great Depression. The break between the two periods is already given by the 1929 Stock Market Crash in October and does not need an Andrews test or some similar procedure to determine when the break occurs. Using interaction terms, we can construct series for the constant, energy price change and economic growth for the later period after 1933 (or 1947). The estimates in Table 4 exclude the post-depression interaction terms for the second-year lagged GDP and the first-year lagged energy price, which were never significant and almost always had t-statistics less than unity. Including these two terms has very little effect on the other coefficients.

The explanatory power of these equations is substantially greater than their counterparts without the interaction terms in Table 3. The first and second-year lagged effects for real GDP are significantly negative in all specifications. Moreover, the first and second-year lagged effects of energy prices are significantly negative for seven of the eight coefficients and barely misses significance (at 6%) for the eighth one. For years after the Great Depression, one must combine the estimates for the interaction terms with those estimated over the full sample. For example, the effect of energy prices lagged two years is often almost zero for the post-1933 years because the positive interaction term essentially cancels the negative coefficient for the second-year energy price lag covering all years. This effect tends to make the dampening of economic growth due to energy prices greater prior to the Great Depression than after it. Simple extrapolations from the coefficients in Table 4 suggest that equilibrium declines in economic growth due to an energy price increase may be about 60 percent more in the earlier period when the energy intensity was greater.[9] One needs to interpret these results cautiously, however, because the historical data underlying this earlier experience may exaggerate the economic output volatility (Sutch, 2006).

Controlling for important historical events such as World War One and the recent Great Recession is an important adjustment if one wants a richer explanation of the economy's response to energy price movements. Table 5 reports results that repeat the estimations shown in Table 4 except that the two yearly dummies for World War One and the recent Great Recession are removed. Although the constant, the post-1933 intercept term, and all the GDP effects remain significant, the second-year lagged coefficients for energy prices are not significant in any of the equations. Moreover, all price effects are noticeably smaller and each equation's explanatory power measured by the adjusted R-squared is noticeably less in Table 5.

All these results are robust when the previously discussed Alternative real GDP estimates replace the Millennial series. Granger causality tests reported in Table 6 continue to reject the hypothesis that lagged energy prices (real or nominal) are unimportant in explaining

[9] Assume that energy prices increase by one percent in each of the past two years. The equilibrium economic growth rate associated with these energy price changes will equal the sum of the two lagged energy price effects divided by one minus the sum of the two lagged GDP effects. Based upon the results in column 3 in Table 4, these computations result in -0.146% for the earlier period and -0.091% for the later period. These magnitudes are purely illustrative and do not represent the impact of an energy price shock on the economy after incorporating all of the other effects that operate in the actual economy.

economic growth for either time period. Meanwhile, there is little evidence that lagged economic growth precedes energy prices. Regression results based upon the Alternative real GDP estimates that include the yearly dummy variables for World War One and the Great Recession and that do not differentiate between pre- and post-1933 responses are shown in Table 7. They are similar to those based upon the Millennial series that were displayed in Table 3. Most importantly, the significance of the lagged energy price effects remains the same. Fewer lagged GDP effects are statistically significant with this GDP series in the sample that excludes 1930-47. These equations for this sample have a lower explanatory power than those based upon the Millennial series shown in Table 3.[10]

6. Conclusion

The results demonstrate that: (a) there is a negative association between changes in energy prices and changes in U.S. GDP in the time before the Great Depression, (b) the earlier economy was more dependent on energy inputs and producing most of its energy without relying upon fuel imports, and (c) the associated economic impacts of energy price increases were higher, perhaps by 60 percent according to the estimates in Table 4, during the period before the Great Depression than during the Post-World War Two period. It is important not to overemphasize this effect. There were clearly other key economic policies and conditions that were shaping the macroeconomic trends during these times. These empirical estimates, however, do show that energy price shocks have deep historical “roots” in the performance of the US economy. At the same, they suggest that there are periods, e.g., during the 1930s or

[10] However, the explanatory power is higher than in Table 3 when only the 1930-33 years are excluded.

perhaps after the 2009 Great Recession, when this relationship may be less pronounced depending upon the state of the economy.

Oscillating energy prices may be a problem, but individuals and firms can adopt strategies that circumvent these cyclical price movements. Sustained energy price shocks caused by sudden and disruptive supply shortfalls, on the other hand, can lead towards serious economic dislocations and unused productive capacity. Sustained energy price increases in the United States have preceded many declines in economic activity as far back as 1890. This finding suggests a much longer national experience with rising energy prices that began well before the period after World War Two. This problem emerged well before the US transition towards petroleum products when coal was an important energy source and when most energy was produced domestically rather than imported.

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Data Appendix

The analysis uses the two Millennial Project series for the period prior to 1929, after converting their 1996-dollar estimates to 2009 counterparts using the GDP deflator provided by the U.S. Bureau of Economic Analysis. It merges this data with the most recently available estimates for real GDP that the U.S. Bureau of Economic Analysis provides for the 1929-2014 period.

The BP crude oil price series is reported from 1861 in dollars per barrel. Prices through 1944 are the US average domestic price as reported below for the BLS oil price series. Thereafter, they represent international rather than domestic crude oil prices. Prices between 1945 and 1983 are for Arabian Light crude oil posted at their Ras Tanura oil facility. Prices after 1983 refer to the Brent crude oil price.

The BLS oil price series are based upon the BLS price index for domestic crude oil. Prior to 1947, they are the average wellhead price as reported in the US Bureau of the Census (1975) Historical Statistics of the United States, Colonial Times to 1970, Part 1. Series M 138-142. The BLS producer price index for domestic crude oil is used to develop price estimates after 1946.

The BLS energy price series before 1926 are the wholesale price index for fuel and lighting reported in the US Bureau of the Census (1975) Historical Statistics of the United States, Colonial Times to 1970, Part 1. Series E 40-51. The BLS producer price index for fuel and power is used to develop price estimates after 1926.

Table 1. Data Summary, 1891-2014

Variable (Change)	Mean	Standard Deviation	Minimum	Maximum
Real GDP (Millennial)	0.032	0.054	-0.141	0.173
Real GDP (Alternative)	0.033	0.050	-0.138	0.173
Crude Oil Price (BP)	0.038	0.251	-0.647	1.258
Crude Oil Price (BLS)	0.035	0.218	-0.605	0.542
Energy Price (BLS)	0.032	0.126	-0.517	0.443

All price and GDP variables are first differences in logarithms.

Table 2. Granger Causality Tests for GDP and Energy Prices, Combined Samples

	GDP Equation		Energy Price Equation	
	Chi-square	Probability	Chi-square	Probability
1892-1929; 1933-2014				
GDP-Energy Prices	10.249*	0.006	0.428	0.807
GDP-Real Energy Prices	6.908*	0.032	0.575	0.682
1892-1929; 1948-2014				
GDP-Energy Prices	14.797*	0.001	0.766	0.750
GDP-Real Energy Prices	8.762*	0.013	0.101	0.951

* Significantly rejects hypothesis that past energy prices do not explain current GDP at 1% level.

Table 3. Estimated Coefficients for Real GDP Equation Since 1892

	(1)	(2)	(3)	(4)
Energy Price Variable	Nominal	Real	Nominal	Real
Excluded Years	1930-33	1930-33	1930-47	1930-47
GDP(t-1)	0.097	0.096	-0.262**	-0.252**
	(0.093)	(0.093)	(0.094)	(0.095)
GDP(t-2)	-0.065	-0.072	-0.214*	-0.213*
	(0.091)	(0.092)	(0.086)	(0.089)
Energy Price(t-1)	-0.101**	-0.098*	-0.085**	-0.08*
	(0.037)	(0.043)	(0.029)	(0.035)
Energy Price(t-2)	-0.055	-0.061	-0.072*	-0.07
	(0.037)	(0.044)	(0.03)	(0.036)
World War One	0.115*	0.098**	0.112**	0.094*
	(0.053)	(0.052)	(0.042)	(0.043)
Great Recession	-0.043	-0.043	-0.056	-0.056
	(0.049)	(0.05)	(0.039)	(0.041)
Constant	0.039**	0.035**	0.051**	0.047**
	(0.007)	(0.006)	(0.006)	(0.006)
Adjusted R-square	0.066	0.041	0.189	0.146

Dependent variable is Millennial Real GDP.
All price and GDP variables are first differences in logarithms.
Standard errors are shown in parentheses.
* indicates 5% significance
** indicates 1% significance

Table 4. Estimated Coefficients for Real GDP Equation Since 1892 Allowing for Post 1933 Breaks

	(1)	(2)	(3)	(4)
Fuel Price	Nominal	Real	Nominal	Real
Excluded Years	1930-33	1930-33	1930-47	1930-47
GDP(t-1)	-0.334**	-0.327**	-0.335**	-0.327**
	(0.116)	(0.117)	(0.103)	(0.105)
GDP(t-2)	-0.233**	-0.243**	-0.231**	-0.240**
	(0.087)	(0.089)	(0.087)	(0.09)
GDP(t-1)>1933	0.935**	0.932**	0.434	0.440
	(0.177)	(0.181)	(0.245)	(0.251)
Energy Price (t-1)	-0.102**	-0.092*	-0.099**	-0.088*
	(0.034)	(0.04)	(0.031)	(0.036)
Energy Price (t-2)	-0.130**	-0.117	-0.129**	-0.115*
	(0.049)	(0.062)	(0.043)	(0.055)
Energy Price (t-2)>1933	0.153*	0.129	0.125*	0.104
	(0.069)	(0.082)	(0.063)	(0.075)
World War One	0.140**	0.110*	0.138**	0.109*
	(0.05)	(0.05)	(0.044)	(0.045)
Great Recession	-0.031	-0.031	-0.045	-0.045
	(0.044)	(0.045)	(0.039)	(0.041)
year>1933	-0.024*	-0.023*	-0.010	-0.010
	(0.011)	(0.011)	(0.012)	(0.012)
Constant	0.051**	0.047**	0.051**	0.047**
	(0.009)	(0.009)	(0.008)	(0.008)
Adjusted R-square	0.260	0.222	0.217	0.158

Dependent variable is Millennial Real GDP.
All price and GDP variables are first differences in logarithms.
Standard errors are shown in parentheses.
* indicates 5% significance
** indicates 1% significance

Table 5. Estimated Coefficients for Real GDP Equation Since 1892 Allowing for Post 1933 Breaks Without Year Dummy Variables

	(1)	(2)	(3)	(4)
Fuel Price	Nominal	Real	Nominal	Real
Excluded Years	1930-33	1930-33	1930-47	1930-47
GDP(t-1)	-0.363**	-0.352**	-0.360**	-0.350**
	(0.119)	(0.119)	(0.107)	(0.108)
GDP(t-2)	-0.202*	-0.216*	-0.192*	-0.206*
	(0.089)	(0.090)	(0.090)	(0.092)
GDP(t-1)>1933	0.960**	0.954**	0.497	0.497
	(0.182)	(0.183)	(0.253)	(0.255)
Energy Price (t-1)	-0.075**	-0.076	-0.073*	-0.073*
	(0.033)	(0.040)	(0.030)	(0.036)
Energy Price (t-2)	-0.080	-0.069	-0.080	-0.069
	(0.047)	(0.058)	(0.042)	(0.053)
Energy Price (t-2)>1933	0.097	0.078	0.074	0.058
	(0.068)	(0.080)	(0.063)	(0.074)
year>1933	-0.029*	-0.027*	-0.016	-0.015
	(0.011)	(0.011)	(0.012)	(0.012)
Constant	0.053**	0.050**	0.052**	0.049**
	(0.009)	(0.009)	(0.008)	(0.008)
Adjusted R-square	0.216	0.197	0.140	0.111

Dependent variable is Millennial Real GDP.
All price and GDP variables are first differences in logarithms.
Standard errors are shown in parentheses.
* indicates 5% significance
** indicates 1% significance

Table 6. Granger Causality Tests for "Alternative GDP" and Energy Prices, Combined Samples

	GDP Equation		Energy Price Equation	
	Chi-square	Probability	Chi-square	Probability
1892-1929; 1933-2014				
GDP-Energy Prices	10.854**	0.004	0.046	0.977
GDP-Real Energy Prices	6.34*	0.042	0.443	0.801
1892-1929; 1948-2014				
GDP-Energy Prices	16.613**	0.000	0.529	0.768
GDP-Real Energy Prices	7.652*	0.022	0.012	0.994

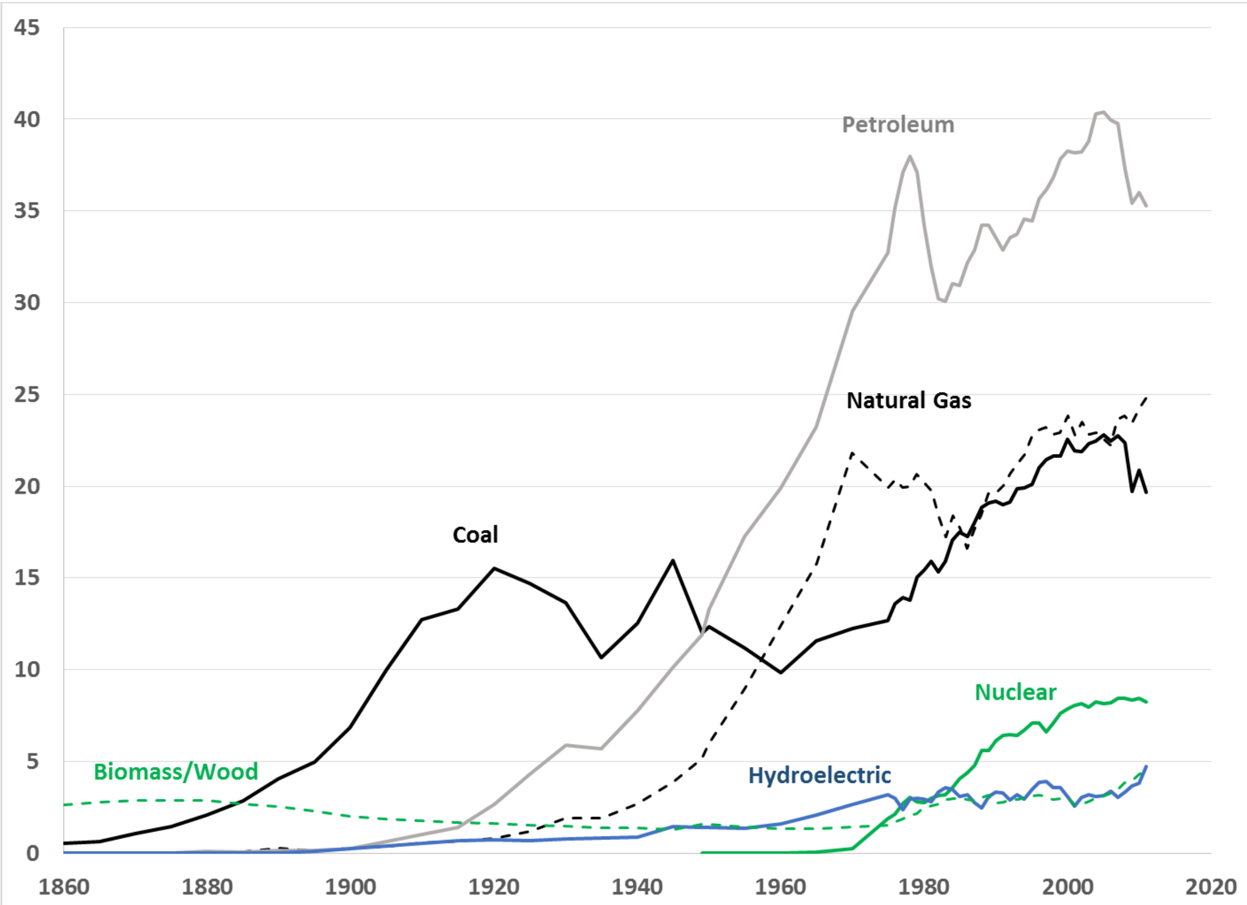
* Significantly rejects hypothesis that past energy prices do not explain current GDP at 5% level.
** Significantly rejects hypothesis that past energy prices do not explain current GDP at 1% level.

Table 7. Estimated Coefficients for Alternative Real GDP Equation Since 1892

	(1)	(2)	(3)	(4)
Energy Price Variable	Nominal	Real	Nominal	Real
Excluded Years	1930-33	1930-33	1930-47	1930-47
GDP(t-1)	0.202*	0.209*	-0.154	-0.130
	(0.093)	(0.094)	(0.096)	(0.098)
GDP(t-2)	-0.018	-0.022	-0.100	-0.092
	(0.092)	(0.094)	(0.088)	(0.092)
Energy Price(t-1)	-0.098**	-0.091*	-0.085**	-0.075*
	(0.033)	(0.039)	(0.026)	(0.031)
Energy Price(t-2)	-0.039	-0.036	-0.059*	-0.046
	(0.033)	(0.039)	(0.027)	(0.032)
World War One	0.090	0.071	0.093*	0.071
	(0.047)	(0.047)	(0.038)	(0.039)
Great Recession	-0.040	-0.040	-0.052	-0.053
	(0.044)	(0.045)	(0.035)	(0.036)
Constant	0.033**	0.030**	0.045**	0.040**
	(0.006)	(0.006)	(0.006)	(0.006)
Adjusted R-square	0.096	0.063	0.142	0.073

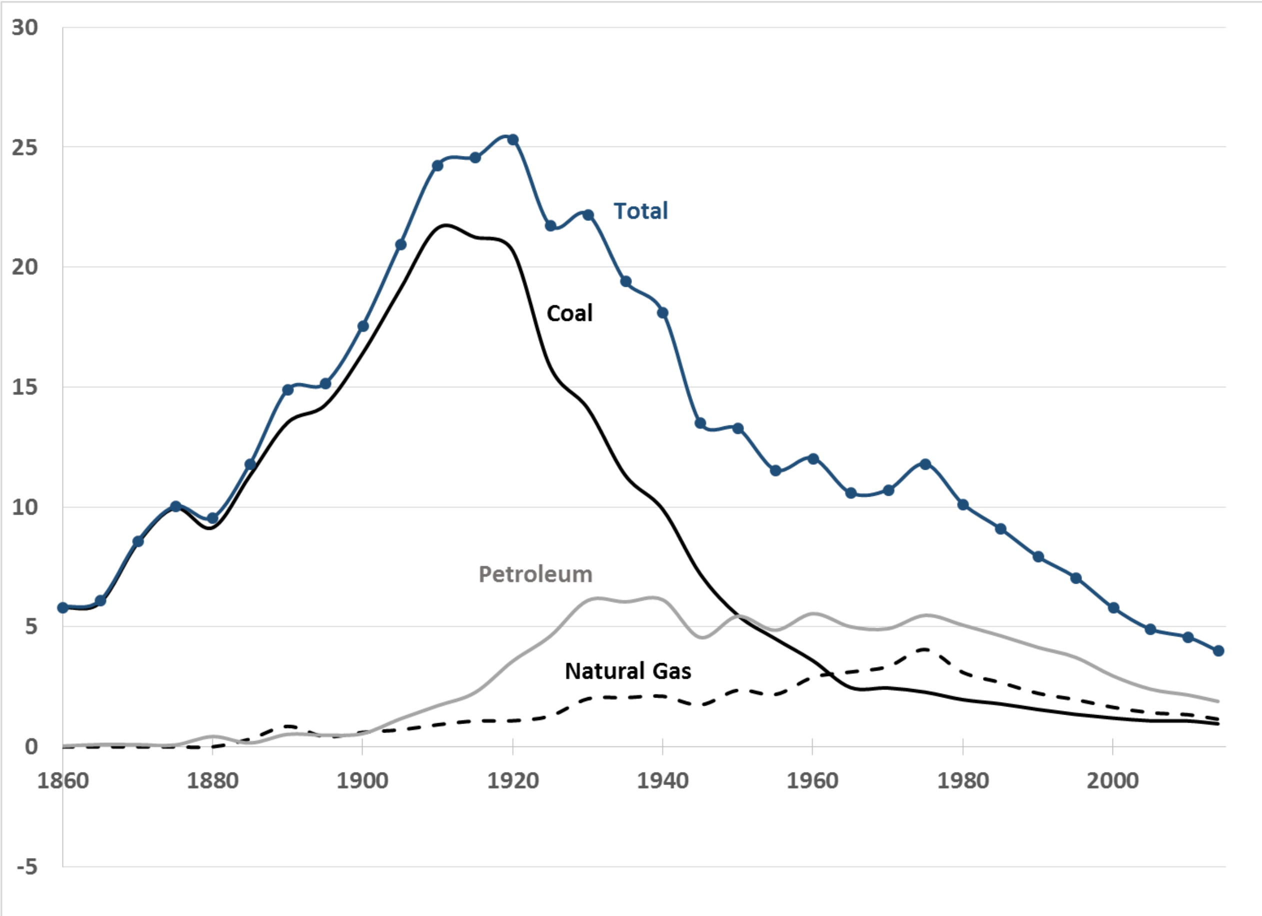
Dependent variable is Alternative Real GDP.
All price and GDP variables are first differences in logarithms.
Standard errors are shown in parentheses.
* indicates 5% significance
** indicates 1% significance

Figure 1. History of US Energy Consumption, 1775-2015 (Quadrillion BTU)



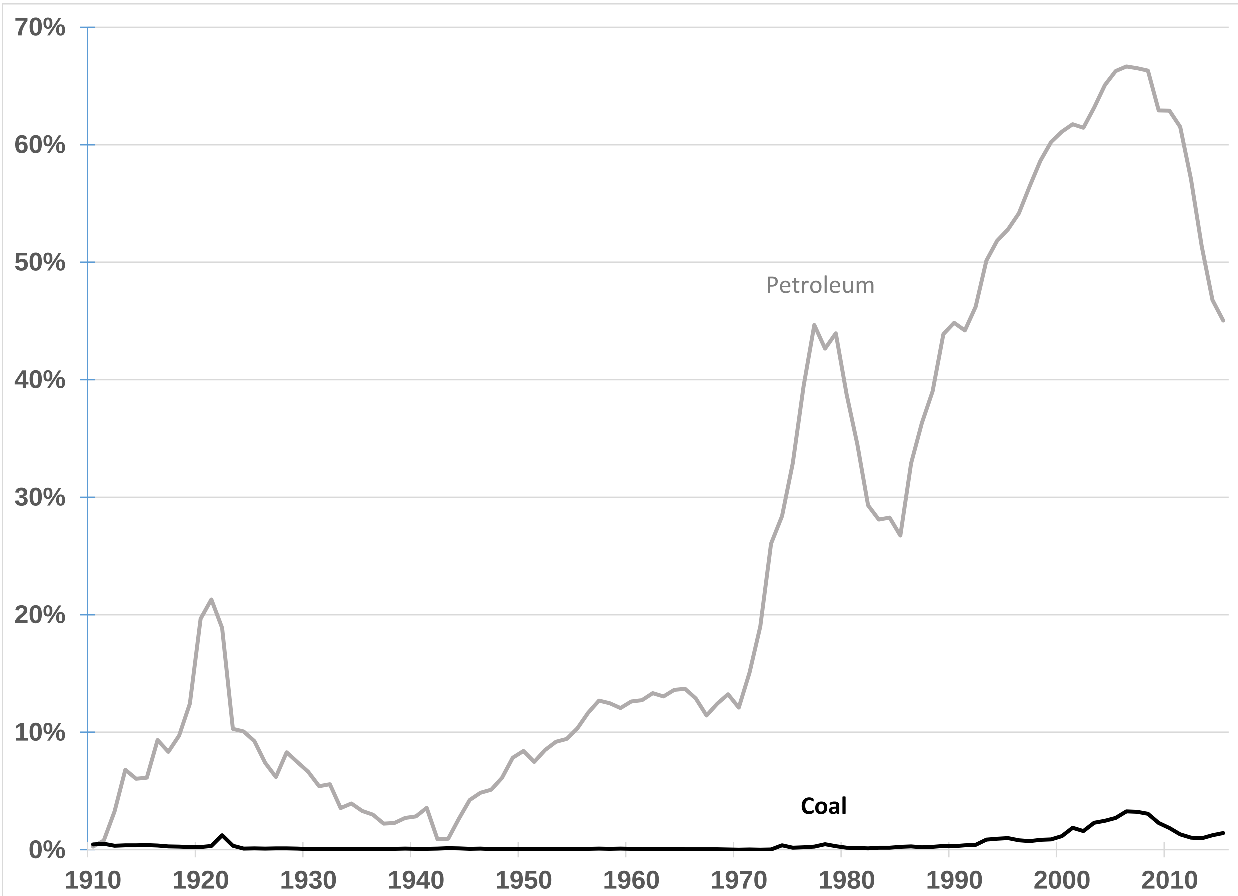
Source: US Energy Information Administration; see Data Appendix.

Figure 2. Energy Intensity (Thousand BTU/2009 US Dollars) for Different Sources, 1860-2010



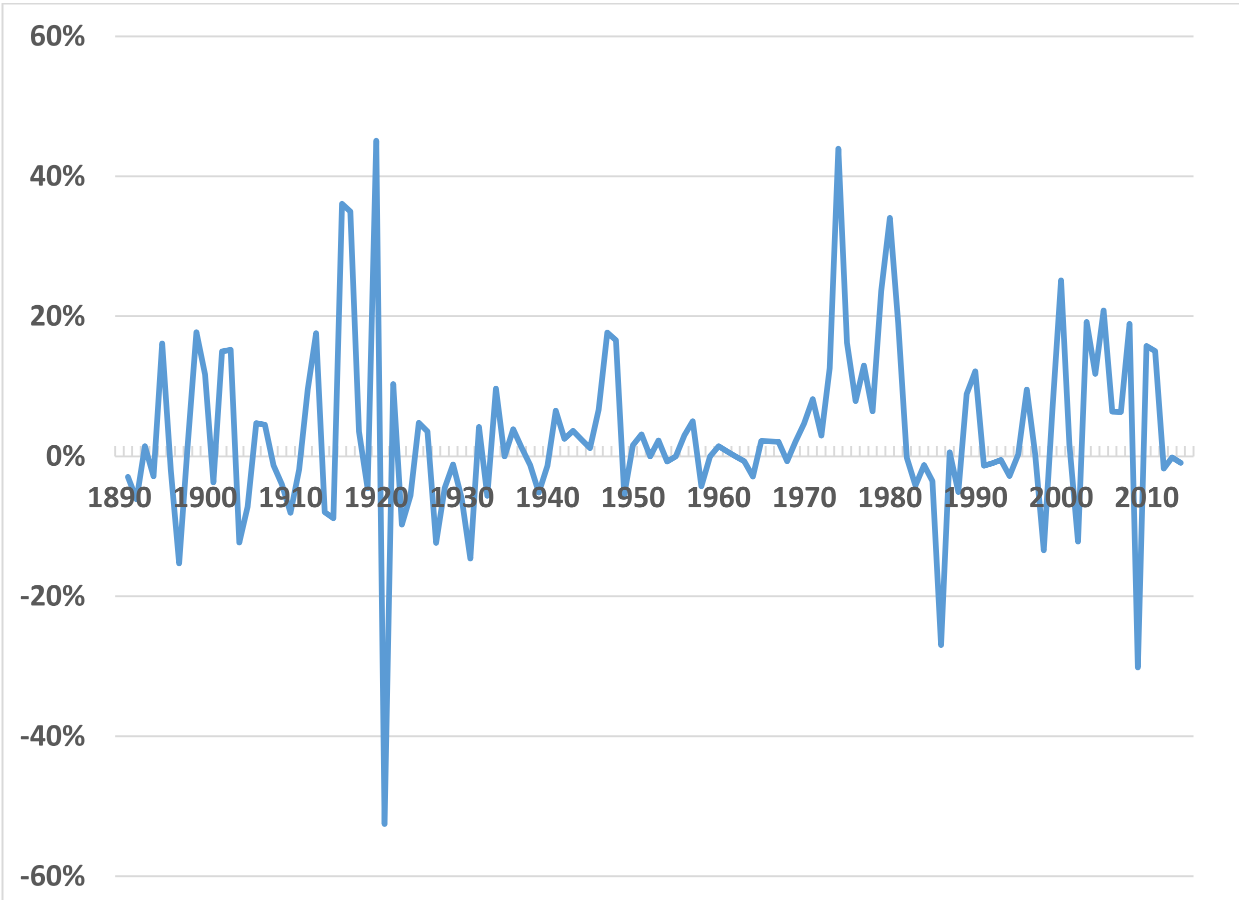
Source: US Energy Information Administration, Carter et al (2006); see Data Appendix.

Figure 3. U.S. Energy Import Shares (%), 1910-2015



Source: US Energy Information Administration.

Figure 4. Percent Change in Average Energy Price, 1890-2014



Source: U.S. Bureau of Labor Statistics, Producer Price Indexes.